1/28/00

A/RE

Please type a plus sign (+) inside this box → [+]

PTO/SB/50 (4/98)
Approved for use through 09/30/2000. OMB 0651-0033
Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

REISSUE PATENT APPLICATION TRANSMITTAL

Address to:

Assistant Commissioner for Patents
Box Patent Application
Washington, DC 20231

Attorney Docket No.	042390.P3294CR
First Named Inventor	Eric C. Hannah
Original Patent Number	5,712,682
Original Patent Issue Date (Month/Day/Year)	01/27/1998
Express Mail Label No.	EL414969674US

APPLICATION FOR REISSUE OF: (check applicable box) ☒ Utility Patent ☐ Design Patent ☐ Plant Patent

APPLICATION ELEMENTS

1. ☒ *Fee Transmittal Form *(PTO/SB/56)* *(Submit an original, and a duplicate for fee processing)*
2. ☒ Specification and Claims *(amended, if appropriate)*
3. ☒ Drawing(s) *(35 U.S.C. 113)*
4. ☒ Reissue Oath / Declaration (original or copy) *(37 C.F.R. § 1.175)(PTO/SB/51 or 52)*
5. Original U.S. Patent
   ☒ Offer to Surrender Original Patent *(37 C.F.R § 1.178)(PTO/SB/53 or PTO/SB/54)*
   or
   ☐ Ribboned Original Patent Grant
   ☐ Affidavit / Declaration of Loss *(PTO/SB/55)*
6. ☒ Original U.S. Patent currently assigned?
   ☒ Yes ☐ No
   (If Yes, check applicable box(es))
   ☒ Written Consent of all Assignees *(PTO/SB/53 or 54)*
   ☐ 37 C.F.R. § 3.73(b) Statement ☐ Power of Attorney

ACCOMPANYING APPLICATION PARTS

7. ☐ Foreign Priority Claim *(35 USC 119)* *(if applicable)*
8. ☐ Information Disclosure Statement (IDS)/PTO - 1449 ☐ Copies of IDS Citations
9. ☐ English Translation of Reissue Oath/Declaration *(if applicable)*
10. ☐ *Small Entity Statement(s) *(PTO/SB/09-12)* ☐ Statement filed in prior application, Status still proper and desired
11. ☒ Preliminary Amendment
12. ☒ Return Receipt Postcard (MPEP 503) *(Should be specifically itemized)*
13. ☐ Other: .....

*NOTE FOR ITEMS 1 & 10: IN ORDER TO BE ENTITLED TO PAY SMALL ENTITY FEES, A SMALL ENTITY STATEMENT IS REQUIRED (37 C.F.R. § 1.27), EXCEPT IF ONE FILED IN A PRIOR APPLICATION IS RELIED UPON (37 C.F.R. § 1.28).

14. CORRESPONDENCE ADDRESS

☐ Customer Number or Bar Code Label (Insert Customer No. or Attach bar code label here) or ☒ Correspondence address below

Name	BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP				
Address	12400 Wilshire Boulevard, Seventh Floor				
City	Los Angeles	State	California	Zip Code	90025
Country	U.S.A.	Telephone	(503) 684-6200	Fax	(503) 684-3245

Name (Print/Type)	Robert A. Diehl, Reg. No. 40,992		
Signature	Robert A. Diehl	Date	1/26/00

Burden Hour Statement: This form is estimated to take 0.2 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Box Patent Application, Washington, DC 20231.

Attorney Docket No. 42390.P3294CR

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Reissue Application No.: Not Yet Assigned

Filed: Concurrently herewith

Patent No.: 5,712,682

Granted: January 27, 1998

Patentee: Eric C. Hannah

Title: CAMERA HAVING AN ADAPTIVE GAIN CONTROL

Commissioner of Patents
and Trademarks
Washington, D.C. 20231

REQUEST FOR ABSTRACT OF TITLE

1. Please prepare a certified Abstract of Title in respect of the above identified original patent for placing in the official file of the Reissue Application which is filed herewith.

2. Title in the name of INTEL CORPORATION was recorded on April 26, 1996, Reel 7993, Frame 0221.

3. For the fee required by 37 CFR 1.19(b)(4) please

X find enclosed a check in the amount of $25.00.
X charge any shortages or credit any overages to Account No. 02-2666.
A duplicate of this request is attached.
__ charge Account No. 02-2666 in the amount of $15.00.
A duplicate of this request is attached.

Date: 1/26/2000

Kenneth M. Seddon
Reg. No. 43,105

12400 Wilshire Boulevard
7th Floor
Los Angeles, California 90025-1026
(503)684-6200

PATENT APPLICATION

042390.P3294C

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:	)	January 26, 2000
Eric C. Hannah	)	
Original Patent Number: 5,712,682	)	Group Art Unit: unknown
Issued: January 27, 1998	)	Examiner: S. Hsia

For: **CAMERA HAVING AN ADAPTIVE GAIN CONTROL**

EL414969674US

"Express Mail" Label Number

JANUARY 26, 2000

Date of Deposit

I HEREBY CERTIFY THAT THE ENCLOSED PETITION IS BEING DEPOSITED WITH THE UNITED STATES POSTAL SERVICE "EXPRESS MAIL" SERVICE UNDER 37 CFR 1.10 ON THE DATE INDICATED ABOVE AND IS ADDRESSED TO THE ASSISTANT COMMISSIONER FOR PATENTS, WASHINGTON, D.C. 20231.

Mary Warner

Name of Person Mailing Paper or Fee

Mary Warner

Signature

PRELIMINARY AMENDMENT FOR REISSUE APPLICATION, OFFER TO SURRENDER THE ORIGINAL PATENT, AND ASSENT OF ASSIGNEE TO REISSUE

HONORABLE ASSISTANT COMMISSIONER FOR PATENTS,
Washington, D.C. 20231

SIR:

In accordance with 35 U.S.C. § 251, Applicant is hereby filing a reissue application with claims that are broader than those issued in the original patent.

Please enter the following amendment prior to examination so that there is a total of seven (7) independent and a total of forty-five (45) claims pending in the application.

AMENDMENT

Amendment to Claims

Please add the following claims as shown below.

23. (Newly added) An apparatus adapted to process an image, comprising:

an amplifier adapted to apply more than one gain level to the image; and

a processor coupled to the amplifier, wherein the processor is capable of adjusting the more than one gain level applied by the amplifier.

24. (Newly added) The apparatus of claim 23, further comprising a sensor coupled to the amplifier provide the amplifier with the image.

25. (Newly added) The apparatus of claim 23, wherein the processor is further capable of providing a control signal to the amplifier to adjust the more than one gain level applied by the amplifier.

26. (Newly added) The apparatus of claim 23, wherein the amplifier is capable of applying different gain levels to different regions of the image.

27. (Newly added) The apparatus of claim 23, wherein the processor is capable of updating a gain map comprising settings applied by the amplifier.

28. (Newly added) The apparatus of claim 27, wherein the gain map is a two dimensional array of gain levels, each gain level indicating a particular gain applied by the amplifier to a corresponding region of the image.

29. (Newly added) The apparatus of claim 27, further comprising a register coupled to the processor and the amplifier.

30. (Newly added) The apparatus of claim 29, wherein the register is capable of storing the gain map and the amplifier is adapted to read the gain levels from the register.

31. (Newly added) The apparatus of claim 25, wherein the processor is further adapted to provide the control signal to the amplifier in real-time.

32. (Newly added) The apparatus of claim 24, wherein the processor is further adapted to analyze the image to determine if the sensor is providing a sufficient level of detail.

33. (Newly added) The apparatus of claim 32, wherein the processor is further adapted to increase the gain level in dark portions of the image and decrease the gain level in bright portions of the image.

34. (Newly added) An apparatus capable of processing an image, comprising:

an image capture device coupled to the apparatus and capable of providing the image;

an amplifier coupled to the camera, wherein the amplifier is adapted to apply at least two gain levels, each to a different region of the image; and

a processor coupled to the amplifier, wherein the processor is adapted to provide a signal to the amplifier to adjust the at least two gain levels.

35. (Newly added) The apparatus of claim 34, wherein the image capture device is a camera.

36. (Newly added) The apparatus of claim 34, wherein the processor is capable of generating a gain map containing gain levels applied by the amplifier.

37. (Newly added) The apparatus of claim 36, wherein the gain map is a two dimensional array of gain levels, each gain level indicating a particular gain applied by the amplifier to a region of the image.

38. (Newly added) The apparatus of claim 37, wherein the processor is capable of dividing the image into a two dimensional array of image regions, each image region being associated with a corresponding level in the gain map.

39. (Newly added) The apparatus of claim 34, further comprising a register coupled to the processor.

40. (Newly added) The apparatus of claim 39, wherein the register is capable of storing a gain map and the amplifier is capable of reading the gain levels from the register.

41. (Newly added) A method of processing an image, comprising:
amplifying a first portion of the image to a first gain level;
amplifying a second portion of the image to a second gain level; and
updating the first gain level and the second gain level in a gain map.

42. (Newly added) The method of claim 41, wherein updating the first gain level and the second gain level is performed in response to clipping of a portion of the image.

43. (Newly added) The method of claim 41, wherein updating the first gain level and second gain level includes increasing the gain level in dark portions of the image and reducing the gain level in bright portions of the image.

44. (Newly added) The method of claim 41, wherein updating the first gain level and the second gain level includes dividing the image into a plurality of image regions, wherein each of the plurality of image regions is associated with a gain level in the gain map.

45. (Newly added) The method of claim 41, further comprising analyzing each image region and updating the associated gain level in response to clipping of the image.

Remarks

Applicant hereby requests that the United States Patent and Trademark Office initiate broadening reissue proceedings for the above-mentioned issued patent. Applicant requests that the preceding claims be added prior to examination.

Specification

A copy of the original patent is filed concurrently with this application. The copy of the original patent was prepared by scanning a copy of the original application as it was filed on December 2, 1996. In addition, the text of the enclosed application has been modified, as required by 37 CFR § 1.173, to reflect the changes made by the preliminary amendment filed on December 2, 1996, the amendment filed on June 10, 1997, and the Certificate of Correction issued on June 9, 1998. These amendments have been shown as normal text as they appear in the original patent. No new matter has been added.

Oath and Declaration

Applicant has filed concurrently with this reissue application an oath and declaration that is believed to meet the requirements of 37 CFR §1.175.

Offer to Surrender the Original Patent

Patent No. 5,712,682 granted to Eric C. Hannah on January 27, 1998 of which Intel Corporation, now sole owner by assignment, and on whose behalf and with whose assent the accompanying application is made, hereby offers to surrender said letter patent.

Assent of Assignee to Reissue

The undersigned assignee of the entire interest in the above-mentioned letters patent hereby assents to the accompanying application.

Drawings for the Reissue Application

In accordance with M.P.E.P. §1413, Applicant hereby requests transfer of the drawings from the file of the original patent in lieu of new drawings. Applicant is enclosing with this reissue application a photocopy of the drawings of the patent as temporary drawings as permitted by 37 CFR § 1.174.

PATENT APPLICATION

042390.P3294C

Request for Abstract of Title Report

Applicant is filing herewith a request for a certified Abstract of Title Report and appropriate fee in accordance with 37 CFR § 1.171.

Support for Amendments.

As indicated above, claims 23-45 have been added. Support for the amendments is at least shown by the examples in FIG. 2-3 and described in Applicant's specification. Support for the amendments can also be found in claims 1-22 of the original patent.

Applicant respectfully submits that no new matter has been added.

Conclusion

Applicant respectfully requests that the Examiner allow all pending claims.

Should it be determined that an additional fee is due under 37 CFR §§1.16 or 1.17, or any excess fee has been received, please charge that fee or credit the amount of overcharge to deposit account #02-2666.

If the Examiner believes that there are any informalities which can be corrected by an Examiner's amendment, a telephone call to the undersigned at (480) 554-9732 is respectfully solicited.

Respectfully submitted,
Eric Hannah

Kenneth M. Seddon

Kenneth M. Seddon
Patent Attorney
Reg. No. 43,105

Dated: 1/26/2000

c/o Blakely, Sokoloff, Taylor & Zafman, LLP
12400 Wilshire Blvd., Seventh Floor
Los Angeles, CA 90025-1026
(503) 264-0967

APPLICATION FOR UNITED STATES LETTERS PATENT

FOR

CAMERA HAVING AN ADAPTIVE GAIN CONTROL

Inventor(s): Eric C. Hannah

Prepared by: Kenneth M. Seddon,
Intellectual Property Attorney

intel®
Intel Corporation
Legal Department
5000 W. Chandler Blvd.
Chandler, AZ 85226-3699

"Express Mail" label number EL414969674US

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to image processing. More specifically, a system for capturing and processing video images.

Background

Digital cameras are used in a variety of applications requiring image capture and image processing. Many applications require cameras which are economical, yet generate a high quality video signal. Typical solid state sensors used in digital cameras have a dynamic range (or light intensity range) of 1000:1 or greater. However, many existing digital cameras utilize an inexpensive 8 bit or 6 bit analog-to-digital (A/D) converter to generate a digital output signal representing the captured image. The use of an 8 bit A/D converter limits the dynamic range of the output signal by providing a maximum of 256 possible luminance levels. Therefore, the dynamic range capabilities of the sensor (1000:1) are compressed to 256:1 by the A/D converter. 'This reduction in dynamic range results in "dipping" of the image; i.e., loss of image detail in bright areas and dark areas of the image. When clipping occurs, dark areas of the image become black (e.g., luminance level 0) and bright areas of the image become white (e.g., luminance level 255).

Existing cameras attempt to compensate for this dynamic range reduction by using an automatic gain control (AGO amplifier having different gain settings. The gain setting of the AGC amplifier is determined based on the total luminance entering the camera. Since a single luminance level is determined, the selected gain setting is applied uniformly to the entire image.

An example of an existing camera is illustrated in Figure 1. A digital camera 10 is attached to an image processor 12. Camera 10 captures an image of scene 14 and generates a digital signal representing the captured image. A solid state sensor 16 in camera 10 captures an image of scene 14. Typical solid state camera sensors are capable of discriminating light intensity over a dynamic range of 1000:1 or greater. Sensor 16 generates a sensor output signal representing the sensed image and provides the signal to an AGC amplifier 18. AGC amplifier 18 applies a particular gain setting to the sensor output signal. A/D converter 20 receives an output signal from AGC amplifier 18. As discussed above, A/D converter 20 may be an 8 bit or 6 bit converter. Using an 8 bit A/D converter 20, the dynamic range of the sensor output signal is compressed to 256:1. Similarly, using a 6 bit A/D converter 20, the dynamic range of the sensor output signal is compressed to 64:1. This dynamic range compression results in a loss of image detail at both ends of the dynamic range; i.e., bright areas and dark areas. As a result, bright areas of the image are compressed into all white regions and dark areas of the image are compressed into all black regions.

AGC amplifier 18 typically has several different gain settings which may be applied to the sensor output signal. The required gain setting for a particular image is selected based on the total light entering camera 10. If the total light level is low, the gain setting is increased. Similarly, if the total light level is high, the gain setting is decreased. The particular gain setting selected is applied uniformly to the entire image. A/D converter 20 generates a digital video output signal on a signal line 22. As discussed above, the dynamic range of the digital video output signal is limited by the capacity of A/D converter 20.

Figure 1 also illustrates image processor 12 coupled to camera 10. Image processor 12 is an optional component, and is not required for proper operation of camera 10. The digital video signal output provided on line 22 may be connected directly to a device capable of accepting

digital signals. The optional image processor 12 includes a video processing circuit 24 and a digital-to-analog (D/A) converter 26. Video processing circuit 24 receives the digital video signal output from line 22 and performs various processing of the signal. Various types of video processing circuits and video processing functions will be known to those skilled in the art. D/A converter 26 receives a signal from the video processing circuit, converts the signal to an analog value, and generates an analog video signal output on signal line 28. This analog video signal may be transmitted to any device capable of receiving analog video signals. '

Problems associated with dynamic range reduction may be solved by utilizing a 10 bit or 12 bit A/D converter to preserve the dynamic range of the sensor output signal. However, 10 bit and 12 bit A/D converters are expensive and substantially increase the cost of the camera. In an application requiring an inexpensive camera, the use of 10 bit or 12 bit . A/D converters is not practical.

It is therefore desirable to provide a low-cost digital camera utilizing an inexpensive A/D converter, yet capable of generating a video signal containing image detail in bright areas and dark areas of the image.

SUMMARY OF THE INVENTION

The present invention provides a digital camera having an inexpensive A/D converter and including a processor for enhancing the dynamic range of the camera. The processor instructs a gain control amplifier to reduce the gain in bright areas of the image and increase the gain in dark areas of the image. These changes in gain settings for different portions of the image increase the image detail provided by the camera, thereby improving the overall image quality.

An embodiment of the present invention provides a sensor for capturing an image and generating a sensor output signal. A gain control amplifier is coupled to the sensor and receives

the sensor output signal. The gain control amplifier has controls for applying various levels of gain to the sensor output signal. An analog-to-digital converter is coupled to the gain control amplifier and generates a digital output signal representing the captured image. A processor is coupled to the analog-to-digital converter and the gain control amplifier. The processor provides a control signal to the gain control amplifier for adjusting the level of gain applied by the amplifier.

Another feature of the present invention provides a gain map containing gain settings applied to the sensor output signal by the gain control amplifier. The gain map is continually updated by the processor to include changes in the captured image.

Other embodiments of the invention provide a register coupled to the processor and the gain control amplifier. The gain map containing gain settings is stored in the register and the gain control amplifier reads the gain settings from the register.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated by way of example in the following drawings in which like references indicate similar elements. The following drawings disclose various embodiments of the present invention for purposes of illustration only and are not intended to limit the scope of the invention.

Figure 1 illustrates a known digital camera and an attached image processor.

Figure 2 is a first embodiment of a camera and processor according to the present invention.

Figure 3 is a flow diagram illustrating operation of the present invention.

Figure 4 is a flow diagram showing the analysis of a captured image and the updating of a gain map used by the camera.

Figure 5 illustrates an exemplary captured image divided into an array of image regions.

Figures 6A-6C illustrate a gain map at different stages of the image processing procedure. - -

Figures 7A-7D illustrate examples of histograms generated for various regions of an image.

Figure 8 is a second embodiment of the invention including a register within the camera.

Figure 9 is a third embodiment of the invention having a processor contained within the camera.

Figure 10 is a fourth embodiment of the invention including additional processing circuitry within the camera.

DETAILED DESCRIPTION

The following detailed description sets forth numerous specific details to provide a thorough understanding of the invention. However, those skilled in the art will appreciate that the invention may be practiced without these specific details. In other instances, well known methods, procedures, components, and circuits have not been described in detail so as not to obscure the invention.

The present invention provides a system for enhancing the dynamic range of a digital camera having an inexpensive A/D converter. An adaptive gain control mechanism is provided for adjusting gain settings applied to a captured image.

A first embodiment of the invention is illustrated in Figure 2. A digital camera 100 contains a sensor 102 for capturing an image representing a scene 104. Sensor 102 may be any type of sensor capable of generating a signal representing a captured image. In a particular embodiment of the invention, sensor 102 is a solid state sensor having a dynamic range of 1000:1 or greater. Sensor 102 generates a sensor output signal representing the captured image. The sensor output signal is provided to a gain control amplifier 106 having controls for applying various levels of gain to the captured image. In an embodiment of the invention, gain control amplifier 106 is an automatic gain control (AGO amplifier capable of receiving and

adjusting the sensor intensity at each pixel site. An analog output signal from AGC amplifier 106 is provided to the input of an analog-to-digital (A/D) converter 108.

As discussed above, A/D converter 108 may be a relatively inexpensive 6 bit or 8 bit A/D converter. To simplify the explanation of the invention, the specification describes camera 100 and its operation when using an 8 bit A/D converter 108.

A/D converter 108 converts the signal received from gain control amplifier 106 from an analog signal to a digital signal. The digital output, of A/D converter 108 is provided on signal line 110 and represents an 8 bit digital video signal of the captured image. As noted above, the dynamic range of the signal on line 110 is limited by the 8 bit capacity of A/D converter 108.

The digital video signal on signal line 110 is also transmitted to a processor 114 using signal line 112. Processor 114 may be any type of processor capable of receiving a digital video signal and performing various operations or calculations related to the received signal. Processor 114 can be a dedicated image processing system or part of a system servicing other devices or performing other functions. In a preferred embodiment of the invention, processor 114 is a personal computer capable of performing a variety of operations and servicing numerous devices. In the preferred embodiment, the personal computer utilizes a Pentium@ processor manufactured by Intel Corporation of Santa Clara, California.

The actual operations and processing steps performed by processor 114 may be implemented in software executed by processor 114. Those skilled in the art will appreciate that processor 114 may be a single processor device capable of processing digital data (e.g., a digital signal processor) or processor 114 may be a complete computer system containing a variety of devices and capable of performing multiple simultaneous operations. Thus, the invention is capable of being implemented on a wide variety of processing devices and computer platforms.

By way of example, the invention will be described in an implementation utilizing a personal computer as processor 114. Numerous type of computers may be used to practice the invention. The computer must be capable of receiving the digital video signal on signal line 112, performing the necessary operations and calculations, and transmitting a control signal to gain control amplifier 106 using a communication line 116. Line 116 functions as a control bus used to communicate control signals and data between processor 114 and gain control amplifier 106. In a specific embodiment of the invention, line 116 is a high-speed serial bus such as a Universal Serial Bus (USB). Although the invention will be described with reference to a high-speed serial bus, any communication line having sufficient bandwidth and low latency may be used to implement the invention.

In the embodiment of Figure 2, processor 114 provides real time control of the gain settings applied by gain control amplifier 106. In this situation, the timely transmission of control signals is important to proper camera operation. A significant amount of bandwidth and low latency is required to ensure that gain control amplifier 106 receives the appropriate control signals when needed. Alternate embodiments of the invention may require a smaller portion of the bandwidth and may tolerate greater latency. These alternate bandwidth and latency requirements will be discussed with respect to the particular embodiments described below.

Figure 3 is a flow diagram illustrating the operation of the system shown in Figure 2. At step 118 an image is captured by sensor 102 in camera 100. At step 120, sensor 102 generates a sensor output signal which is provided to gain control amplifier 106. At step 122, gain control amplifier 106 determines appropriate gain settings for various regions of the captured image and applies the gain to the corresponding region of the image. The gain settings are provided to gain control amplifier 106 by processor 114 using line 116. Additional details

regarding the determination of particular gain settings and dividing the captured image into regions are provided below with reference to Figure 4.

At step 124 of Figure 3, gain control amplifier 106 generates a gain control output signal and provides the signal to A/D converter 108. At step 126, A/D converter 108 converts the gain control output signal from an analog signal to a digital video output signal. Finally, at step 128, processor 114 analyzes the digital video output signal and updates the gain settings, as needed, for various regions of the captured image. The steps of Figure 3 are performed repeatedly to capture and analyze a series

of images.

Referring to Figure 4, a flow diagram illustrates the analysis of a captured image and the updating of a gain map used by camera 100. One example of a gain map 148 is illustrated in Figure 6A as a two dimensional array of gain settings. The gain settings may be represented in decibels (dB) or any other format capable of indicating the gain to be applied by gain control amplifier 106. Each gain setting indicates a specific gain level to be applied by gain control amplifier 106 to a particular region of the captured image. Gain map 148 includes eight rows and eight columns to create 64 gain map cells 150. Figure 6A illustrates a default gain map including a zero value stored in each cell 150 of the gain map. These default gain settings are generated when the system is initialized or reset. During operation of camera 100 and associated processor 114, the gain settings in the gain map are updated to enhance the dynamic range of the digital video output signal, thereby increasing the level of detail provided in the digital video signal. In the embodiment of Figure 2, gain map 148 is stored in a register or other memory device within processor 114.

Referring again to Figure 4, the procedures illustrated in the flow diagram are performed by processor 114 (shown in Figure 2). Step 132 initializes a row counter and a column counter

used to indicate a particular image region and a particular cell of gain map 148 being analyzed or updated. At step 134, the captured image is divided into an array of image regions. Figure 5 illustrates an example of a captured image 152 divided into a two dimensional array of image regions 154. For purposes of explanation, Figure 5 illustrates the actual scene and does not show areas of clipping caused by the A/V converter.

Image 152 is divided into eight rows and eight columns, creating 64 image regions 154. Each image region 154 is associated with a particular gain setting contained in a corresponding cell of gain map 148 (Figure 6A). Image region (2, 4) is a notation indicating the image region at the intersection of row 2 and column 4. The gain level applied to image region (2, 4) is stored in the gain map at cell (2, 4). Thus, each gain map cell provides a gain level to be applied to the corresponding image region. Although Figures 5 and 6A illustrate two dimensional arrays having eight rows and eight columns, any number of rows and columns may be used. As the number of rows and columns is increased, the size of each image region decreases, resulting in more precise gain adjustments to the captured image. However, additional processing resources are required to analyze the captured image as the number of rows and columns are increased.

At step 136 of Figure 4, the image region indicated by the row and column counters is analyzed by processor 114. Initially, the row and column counters are set to identify image region (1, 1). The counters are incremented for each subsequent cycle of the procedure until all image regions have been analyzed. Processor 114 determines the light level in various portions of the image region being analyzed. At step 138, the routine determines whether the image region contains significant bright portions; i.e., whether image detail has been lost or "dipped" due to the 8 bit limitations of the A/D converter. If the image detail has been dipped at step 138, then the gain map setting for the image region being analyzed is updated at step 140. Gain settings are updated gradually (e.g., I dB - 5 dB) until sufficient image detail is provided in each

region of the captured image. Gain settings are continually updated to compensate for changes in the captured image, such as changes in light levels and changes in objects appearing in the captured image.

If image detail has been clipped from the image region at step 138 due to brightness, then the gain map setting for that region is reduced at step 140 to provide increased image detail; i.e., instead of producing all white regions, the gain setting is reduced to prevent clipping and provide enhanced image detail.

If significant bright portions are not identified at step 138, then step 142 determines whether the image region being analyzed contains significant dark portions; i.e., whether image detail has been lost or clipped by the 8 bit A/D converter. If image detail has been lost at step 142, then the gain map setting for that region is increased at step 140 to provide increased image detail. By increasing the gain setting, previously all black portions of the region may begin to show some image detail, thereby increasing the overall image quality.

If the image region being analyzed does not contain significant bright portions or significant dark portions, then the routine continues to step 144 without updating the gain map setting for the particular image region. Step 144 determines whether the current row and column counters indicate the last row and column of the captured image. If all image regions have been analyzed, then the routine ends. Otherwise, the routine branches to step 146 where the row and/or column counters are incremented to select the next image region of the captured image. The routine then returns to step 136 to analyze the next image region. The image regions may be analyzed in any order, Row and column counters represent an example of a mechanism for analyzing each image region in a systematic manner.

When all regions of a captured image have been analyzed according to the procedure illustrated in Figure 4, the updated gain map settings are applied to the next captured image by

gain control amplifier 106 (Figure 2). The digital video signal generated using the new gain settings is then analyzed by processor 114 using the procedure shown in Figure 4 to further update the gain map settings. Thus, the gain map settings are continually updated to maximize the image detail produced in the digital video signal generated by camera 100.

A particular example of the operations performed in Figure 4 will be described with respect to the captured image shown in Figure 5 and the gain maps illustrated in Figures 6A-6C. Figure 6A illustrates a default gain map indicating the gain level applied to each region of the first captured image. When camera 100 captures the first image, processor 114 has no previous image data from which to generate gain settings. Therefore, processor 114 supplies a default gain map to camera 100 for the first captured image.

After capturing the first image, processor 114 divides the image into an array of image regions 154, as shown in Figure 5. Each region 154 is analyzed by processor 114 to determine whether the gain setting for the region should be adjusted to provide increased image detail. Using Figure 5 as the first captured image, certain regions of the image are bright (in the area of the window and the sun), certain regions are dark (in the corner of the room to the left of the window), and other regions have an average light level (near the desk below the window). Processor 114 decreases the gain setting associated with bright regions and increases the gain setting associated with dark regions.

Figure 6B illustrates an updated version of gain map 148 after processor 114 has analyzed the first captured image and adjusted the gain settings accordingly. The gain settings illustrated in Figure 6B are then provided to gain control amplifier 106 for adjusting the gain of the next captured image. As shown in Figure 6B, the gain settings have been increased along the left side of the image (especially in the upper left portion) in an attempt to reduce clipping in that area and enhance image details. Gain settings in the bright area of the window in the upper

right portion of the image have been reduced to enhance image details. Gain settings around the desk (below the window) are unchanged because a sufficient level of detail is already present. As discussed above, gain settings are adjusted in small increments (e.g., 1 dB - 5 dB) until sufficient image detail is provided in the particular region. This provides a gradual change in the image detail, rather than sharp or significant changes between captured images.

The gain settings illustrated in Figure 6B are applied by camera 100 to the second captured image. For this example, the second captured image is the same as Figure 5; i.e., the scene being captured has not changed since the first image was captured. Since gain setting adjustments are performed gradually, the second captured image requires additional gain setting adjustments to further enhance image details. The digital video output generated by applying the gain settings of Figure 6B to the second captured image is provided to processor 114 for analysis. As described with respect to the first analysis the second captured image is divided into an array of image regions 154. Each image region 154 is analyzed and the associated gain setting updated to enhance the image details in the region. The results of the second analysis are illustrated in Figure 6C. Certain gain settings in the upper left portion of the gain map have been increased to provide additional image details in the dark areas. Gain settings in the bright window area have been further reduced to enhance image details. The updated gain settings illustrated in Figure 6C will be used by camera 100 to adjust the gain of the next captured image.

The process of capturing an image, applying settings contained in a gain map to the image, and analyzing the digital video output signal to update gain settings is performed repeatedly by the system illustrated in Figure 2. The gain settings contained in the gain map are updated in response to changes in the captured image; e.g., changes in light level, movement of

objects in the image, and the like. Thus, the processor is repeatedly updating the gain map settings to enhance the overall image detail provided in the digital video output signal.

Those skilled in the art will appreciate that various methods may be used by processor 114 to analyze light intensity in each image region. An embodiment of the invention applies a histogram equalization algorithm to each image region. The histogram equalization algorithm generates a histogram of pixel luminance values in a particular region. The histogram is used to identify areas of high luminance and low luminance; i.e., areas requiring gain adjustments. Several exemplary histograms are illustrated in Figures 7A-7D. Figures 7A-7D are provided for illustration purposes and are not drawn to scale or drawn using the same scale.

Figure 7A is a histogram for an image region having a high luminance value. The histogram illustrates a large number of pixels having a maximum luminance value of 255 (for an 8 bit A/D converter). This histogram may correspond to an image region of Figure 5 in the area of the window. In this situation, histogram equalization is performed to generate an increased number of pixels having values less than 255, thereby enhancing image details in the region.

Figure 7B is a histogram for an image region having a low luminance value, indicated by the large number of pixels having a luminance value of zero (the minimum luminance value). This histogram may correspond to an image region on the left side of Figure 5. In this situation, histogram equalization is performed to generate an increased number of pixels having values greater than zero to enhance image details in the region.

Figure 7C is a histogram for an image region having both low luminance values and high luminance values, but few intermediate values. The histogram in Figure 7C identifies a transition region; i.e., a transition between a bright area and a dark area. These regions may receive little or no gain adjustment because both extremes of brightness and darkness are represented in the same image region. If the gain is increased, additional pixels may be increased to a value of 255

resulting in additional loss of detail in the bright areas. Similarly, if the gain is reduced, additional pixels may be decreased to a value of zero resulting in additional loss of detail in the dark areas.

Figure 7D is a histogram for an image region having a relatively uniform distribution of pixel luminance values throughout the region. This histogram may correspond to an image region under the window in Figure 5. In this situation, the histogram is already substantially equalized, and no gain adjustments are necessary.

In addition to the histogram equalization algorithm discussed above, various methods and algorithms for smoothing sharp edges and transitions between adjacent image regions will be known to those skilled in the art. These methods and algorithms may be utilized with the present invention to provide smoothing in transition areas and between adjacent image regions.

As noted above, Figure 2 illustrates a first embodiment of the invention including camera 100 and processor 114 coupled to the camera. Figures 8-10 illustrate alternate embodiments of the invention. The operation of these alternate embodiments is similar to the operation described above with reference to Figures 3 and 4.

Referring to Figure 8, a second embodiment of the invention is illustrated. A camera 156 includes sensor 102, gain control amplifier 106, and A/D converter 108 as described above with respect to Figure 2. Camera 156 generates a digital video signal on line 110 which is coupled to processor 114 using signal line 112. Processor 114 receives the digital video signal, divides the signal into a plurality of image regions, and analyzes each region as described above with respect to Figures 4, 5, and 6A-6C. Camera 156 also includes a register 160 coupled to processor 114 using a communication line 158. Register 160 is also coupled to gain control amplifier 106 using signal line 162. Register 160 is capable of receiving and storing a gain map from processor 114 and providing the gain map settings to gain control amplifier 106 as

necessary. Register 160 may be a relatively small register, capable of storing a single copy of the gain map. Gain setting updates and control signals generated by processor 114 are communicated to register 160 using line 158. Register 160 stores the updated gain settings for use by gain control amplifier 106.

The addition of register 160 to camera 156 increases the cost of the camera slightly, but eliminates the dependence of gain control amplifier 106 on communication line 116 (Figure 2) to receive gain settings contained in the gain map. If communication line 158 in Figure 8 is shared by other devices and becomes congested, gain setting updates may not be communicated to register 160 in a timely manner. In this situation, gain control amplifier 106 uses the current gain settings contained in register 160 to adjust the gain of a recently captured image. Therefore, this embodiment of the invention may be used with a communication line 158 having a smaller available bandwidth and greater latency because the processor is not providing gain settings to the gain control amplifier in real time. Instead, the gain settings are stored in register 160 and are always available to the gain control amplifier, even if communication line 158 is congested.

Referring to Figure 9, a third embodiment of the invention is illustrated. A camera 164 includes sensor 102, gain control amplifier 106, and A/D converter 108 as described above with respect to Figure 2. A digital video signal is provided on a signal line 166 to a processor 168 located within camera 164. Processor 168 is coupled to gain control amplifier 106 using line 170. The operation' of the camera shown in Figure 9 is similar to the operation of the system in Figure 2. Camera 164 is different from camera 100 (Figure 2) in that processor 168 is contained within the camera rather than positioned external to the camera. In this situation, processor 168 is used exclusively by the camera. Therefore, processor 168 only requires processing capacity to support the operations of the camera. Although the addition of processor 168 within camera

164 increases the overall cost of the camera, connections associated with an external processor (as shown in Figure 2) are eliminated.

Referring to Figure 10, a fourth embodiment of the invention is shown. A camera 172 includes sensor 102, gain control amplifier 106, and A/D converter 108 as described above with respect to Figure 2. Additionally, camera 172 includes a video processing circuit 180 coupled to A/D converter 108 via signal line 174. A digital-to-analog (D/A) converter 182 is coupled to circuit 180 and generates an analog video output signal on output line 184. Processor 114 is coupled to A/D converter 108 using line 176 and coupled to gain control amplifier 106 using communication line 178. The operation of the camera shown in Figure 10 is similar to the operation of the system in Figure 2. Camera 172 differs from camera 100 (Figure 2) by including circuit 180 and D/A converter 182 within the camera such that the camera produces an analog video output signal. Video processing circuit 180 may be capable of performing a variety of different video processing functions, as will be known to those skilled in the art.

From the above description and drawings, it will be understood by those skilled in the art that the particular embodiments shown and described are for purposes of illustration only and are not intended to limit the scope of the invention. Those skilled in the art will recognize that the invention may be embodied in other specific forms without departing from its spirit or essential characteristics. References to details of particular embodiments are not intended to limit the scope of the claims.

CLAIMS

1. A camera comprising:

a sensor configured to capture an image and generate a sensor output signal representing the captured image;

an amplifier coupled to receive the sensor output signal, wherein the amplifier is configured to apply multiple gain levels to the sensor output signal; and

a processor coupled to the amplifier, wherein the processor is configured to provide a control signal to the amplifier to adjust the gain levels applied by the amplifier.

2. The camera of claim 1 wherein the amplifier applies different gain levels to different regions of the captured image.

3. The camera of claim 1 wherein the processor generates a gain map containing gain settings applied to the sensor output signal by the amplifier.

4. The camera of claim 3 wherein the gain map is continually updated by the processor to include changes in the captured image.

5. The camera of claim 3 wherein the gain map is a two dimensional array of gain settings, each gain setting indicating a particular gain applied by the amplifier to a corresponding region of the captured image.

6. The camera of claim 3 further including a register coupled to the processor and the amplifier.

7. The camera of claim 6 wherein the gain map is stored in the register and the amplifier reads the gain settings from the register.

8. The camera of claim 1 wherein the processor provides the control signal to the amplifier in real-time.

9. The camera of claim 1 wherein the processor analyzes the sensor output signal to determine whether a sufficient level of detail is provided in the sensor output signal.

10. The camera of claim 9 wherein the processor increases the gain levels in dark portions of the captured image and the processor decreases the gain levels in bright portions of the captured image.

11. An apparatus for capturing an image, comprising a camera, including:

a sensor configured to capture the image and generate a sensor output signal representing the captured image;

an amplifier coupled to receive the sensor output signal, wherein the amplifier has controls to apply multiple gain levels to the sensor output signal; and

a processor coupled to the camera, wherein the processor is configured to receive the sensor output signal, and wherein the processor is configured to provide a control signal to the amplifier to adjust the gain level applied by the amplifier.

12. The apparatus of claim 11 wherein the processor generates a gain map containing gain settings applied to the sensor output signal by the amplifier.

13. The apparatus of claim 12 wherein the gain map is a two dimensional array of gain settings, each gain setting indicating a particular gain applied by the amplifier to a region of the captured image.

14. The apparatus of claim 13 wherein the processor divides the captured image into a two dimensional array of image regions, each image region associated with a corresponding gain setting in the gain map.

15. The apparatus of claim 12 wherein the camera further includes a register coupled to the processor and the amplifier.

16. The apparatus of claim 15 wherein the gain map is stored in the register and the amplifier reads the gain settings from the register.

17. A method for enhancing the dynamic range of a sensor output signal representing a captured image, the method comprising the steps of:

amplifying the sensor output signal in response to gain settings contained in a gain map, wherein each gain setting is associated with a particular region of the captured image; and

updating the gain settings contained in the gain map in response to changes in the sensor output signal.

18. The method of claim 17 wherein the step of updating the gain settings is performed in response to clipping of the amplified sensor output signal.

19. The method of claim 17 wherein the step of updating the gain settings includes increasing the gain settings in dark portions of the image and reducing the gain settings in bright portions of the image.

20. The method of claim 17 wherein the step of updating the gain settings includes dividing the captured image into a plurality of image regions, wherein each image region is associated with a particular gain setting in the gain map.

21. The method of claim 17 further including the step of analyzing each image region and updating the associated gain setting in response to clipping of the amplified sensor output signal in the image region.

22. An apparatus for capturing an image and generating a signal representing the captured image, comprising:

means for amplifying the signal in response to gain settings contained in a gain map, wherein each gain setting is associated with a particular region of the captured image;

means for updating the gain settings contained in the gain map; and

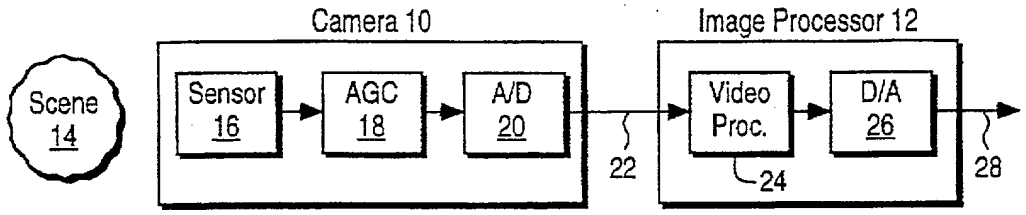
means for generating a control signal indicating a particular gain setting to be applied to a portion of the signal representing the captured image.

ABSTRACT OF THE DISCLOSURE

A system for generating a digital output signal representing a captured image includes a sensor for capturing the image and generating a sensor output signal. A gain control amplifier is coupled to the sensor and receives the sensor output signal. The gain control amplifier has

controls for applying various levels of gain to the sensor output signal. An analog-to-digital converter is coupled to the gain control amplifier and generates the digital output signal representing the captured image. A processor is coupled to the analog-to-digital converter and the gain control amplifier. The processor provides a control signal to the gain control amplifier for adjusting the level of gain applied by the amplifier.

FIG. 1 (Prior Art)



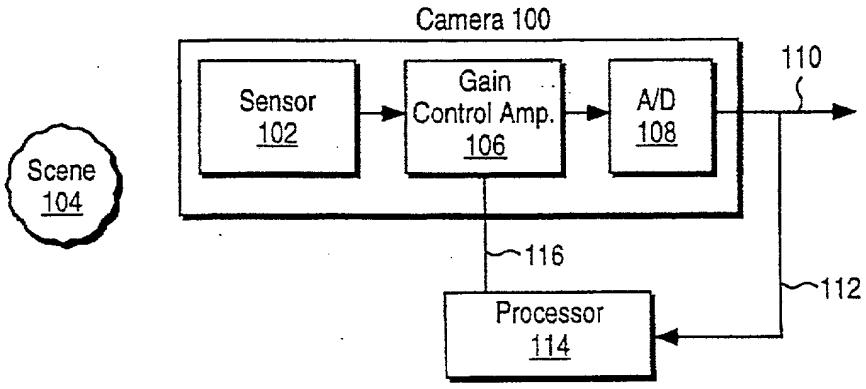


FIG. 2

FIG. 3

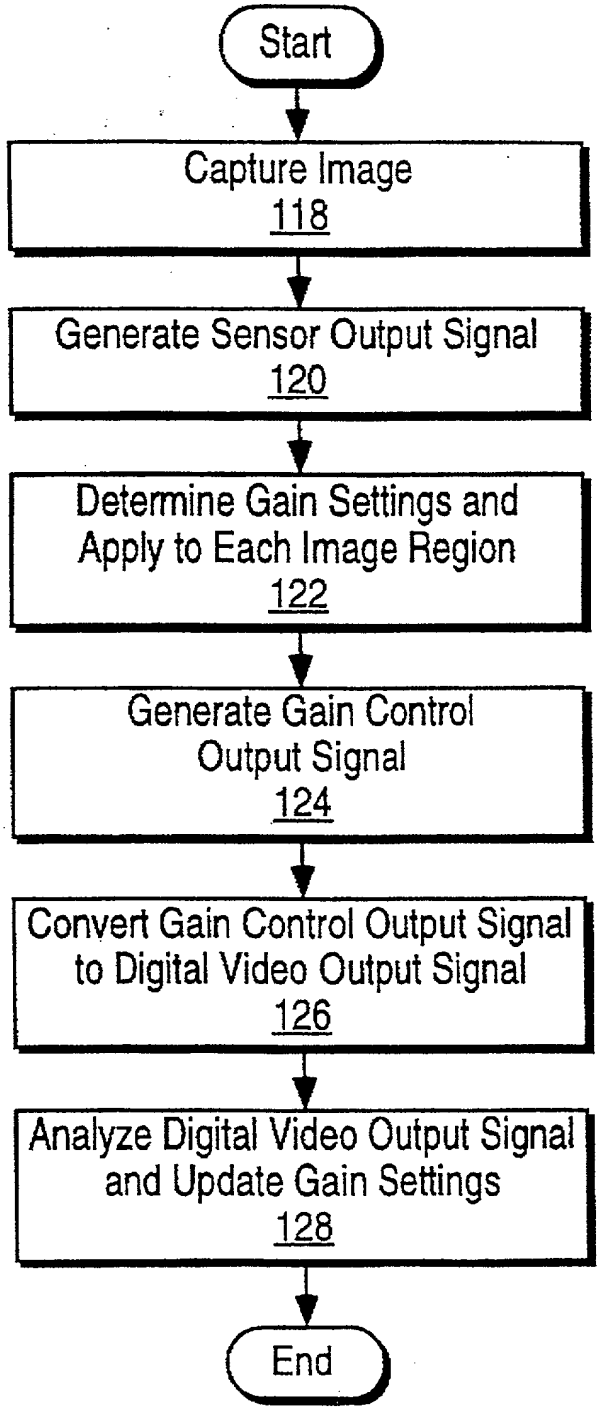

Start
Capture Image
118
Generate Sensor Output Signal
120
Determine Gain Settings and
Apply to Each Image Region
122
Generate Gain Control
Output Signal
124
Convert Gain Control Output Signal
to Digital Video Output Signal
126
Analyze Digital Video Output Signal
and Update Gain Settings
128
End

FIG. 4

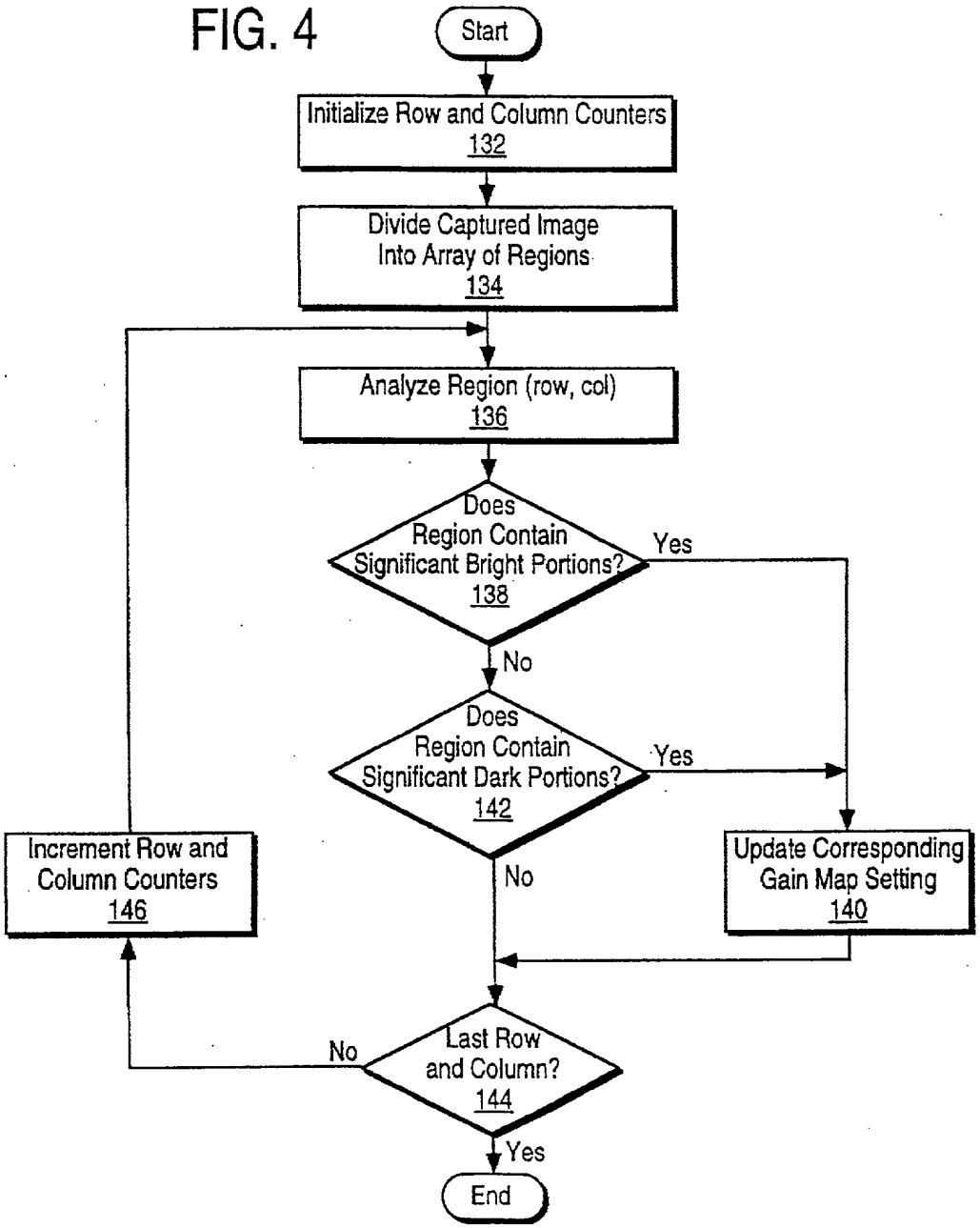

Start
Initialize Row and Column Counters
132
Divide Captured Image
Into Array of Regions
134
Analyze Region (row, col)
136
Does
Region Contain
Significant Bright Portions?
138
Yes
No
Does
Region Contain
Significant Dark Portions?
142
Yes
No
Update Corresponding
Gain Map Setting
140
Increment Row and
Column Counters
146
Last Row
and Column?
144
No
Yes
End

FIG. 5

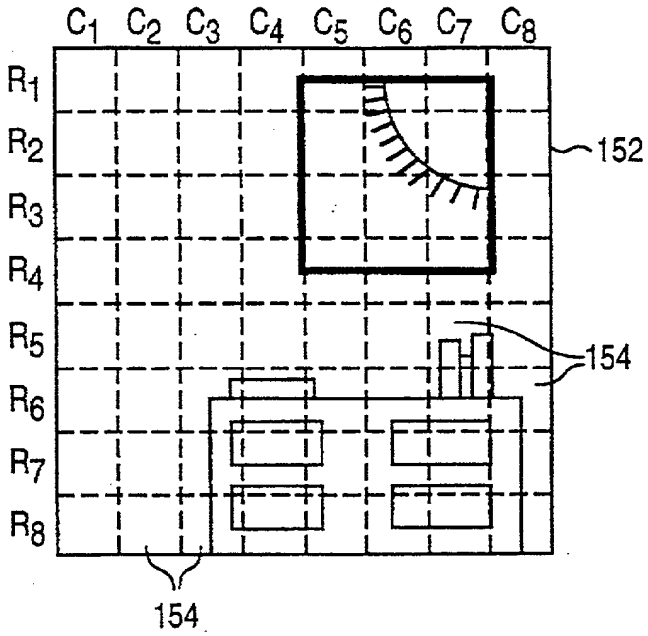


FIG. 6A

	1	2	3	4	5	6	7	8
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0

148
150
150

FIG. 6B

	1	2	3	4	5	6	7	8
1	5	3	2	1	-1	-1	-1	1
2	5	3	2	1	-3	-5	-5	1
3	3	2	1	1	-3	-3	-4	1
4	3	2	0	1	-1	-1	-1	1
5	2	1	0	0	0	0	0	0
6	1	1	0	0	0	0	0	0
7	1	1	0	0	0	0	0	0
8	1	1	0	0	0	0	0	0

148

FIG. 6C

	1	2	3	4	5	6	7	8
1	6	4	2	1	-1	-1	-1	1
2	5	4	2	1	-3	-6	-6	1
3	4	3	1	1	-3	-4	-5	1
4	3	2	1	1	-1	-2	-2	1
5	2	1	0	0	0	0	0	0
6	1	1	0	0	0	0	0	0
7	1	1	0	0	0	0	0	0
8	1	1	0	0	0	0	0	0

148

FIG. 7A

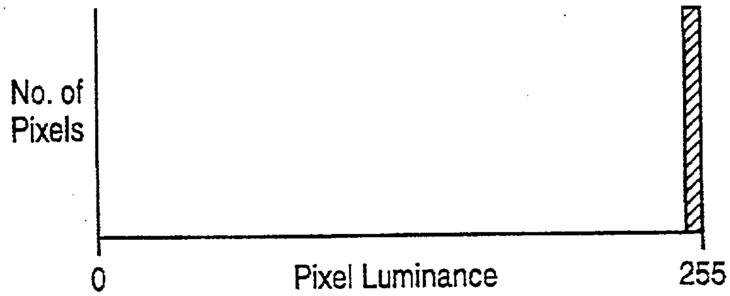


FIG. 7B

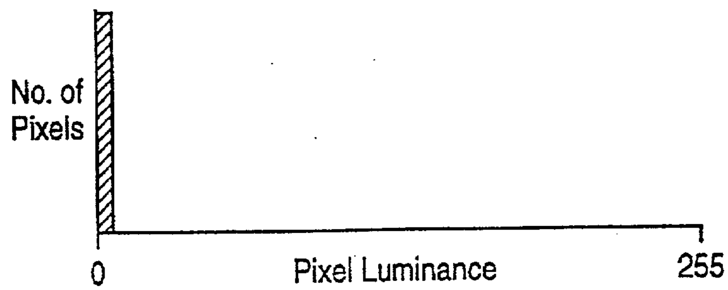


FIG. 7C

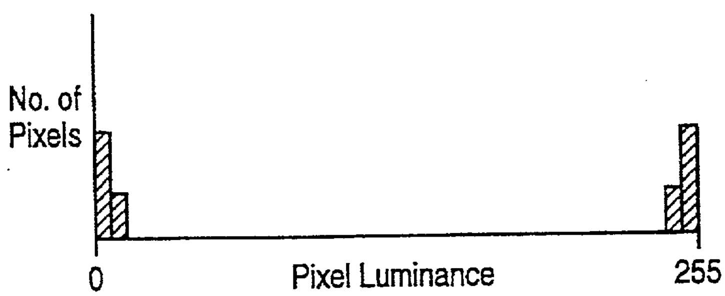
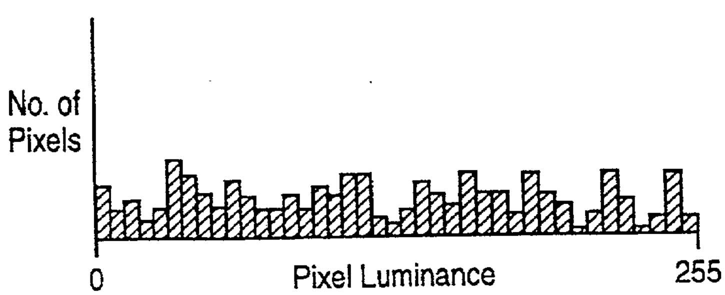


FIG. 7D



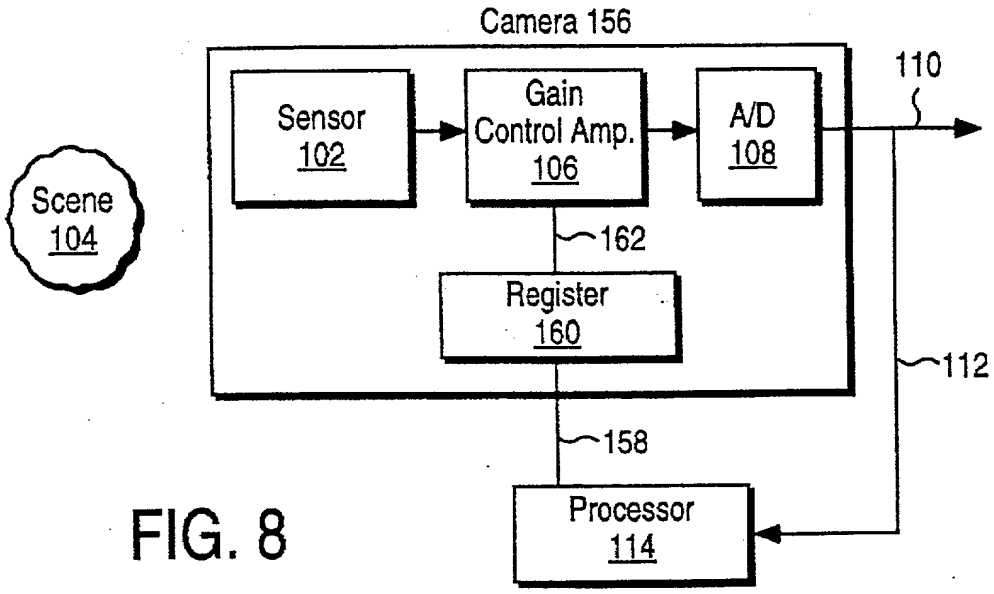

Camera 156
Scene
104
Sensor
102
Gain
Control Amp.
106
A/D
108
110
162
Register
160
112
158
Processor
114

FIG. 8

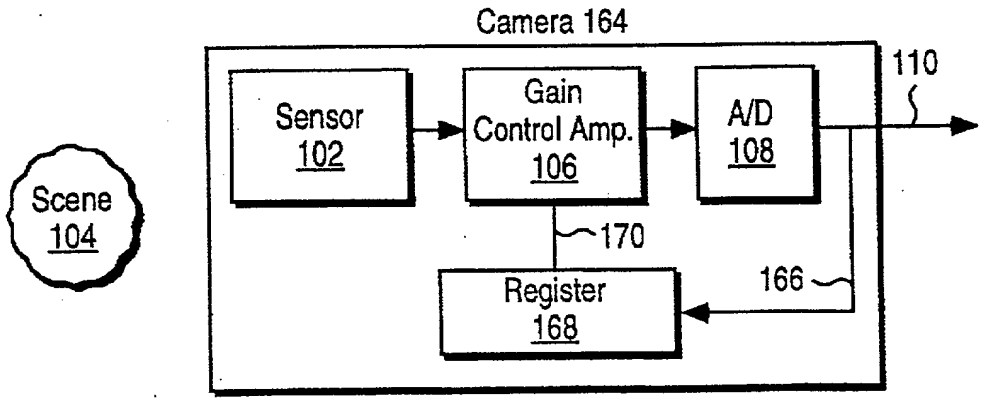
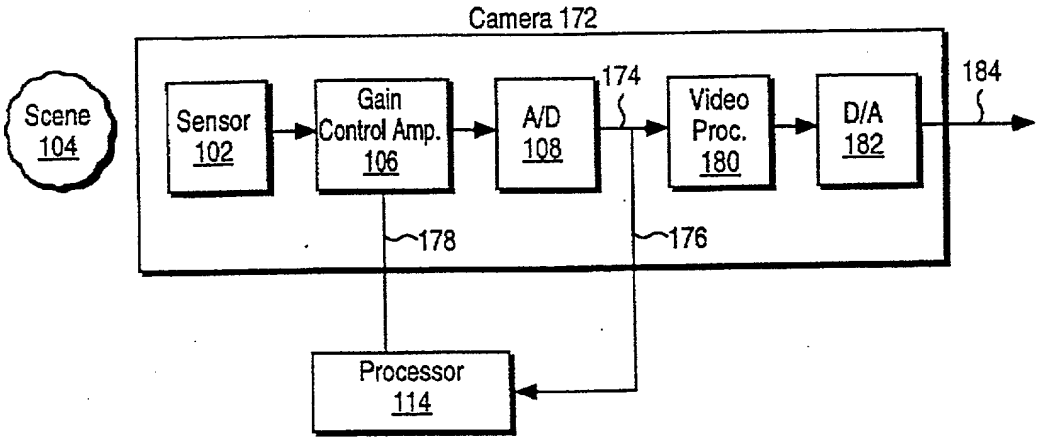

Camera 164
Scene
104
Sensor
102
Gain
Control Amp.
106
A/D
108
110
170
166
Register
168

FIG. 9

FIG. 10


Camera 172
Scene
104
Sensor
102
Gain
Control Amp.
106
A/D
108
174
Video
Proc.
180
D/A
182
184
178
176
Processor
114

Attorney's Docket No.: 42390.P3294CR Patent

DECLARATION AND POWER OF ATTORNEY FOR REISSUE PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below, next to my name.

I believe I am the original, first, and sole inventor (if only one name is listed below) or an original, first, and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

CAMERA HAVING AN ADAPTIVE GAIN CONTROL

the specification of which is attached hereto and was issued as U.S. Patent No. 5,712,682 (the "original patent") from application number 770,386 filed December 2, 1996 (the "original application").

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claim(s), as amended by any amendment referred to above. I do not know and do not believe that the claimed invention was ever known or used in the United States of America before my invention thereof, or patented or described in any printed publication in any country before my invention thereof or more than one year prior to the original application, that the same was not in public use or on sale in the United States of America more than one year prior to the original application, and that the invention has not been patented or made the subject of an inventor's certificate issued before the date of the original application in any country foreign to the United States of America on an application filed by me or my legal representatives or assigns more than twelve months (for a utility patent application) or six months (for a design patent application) prior to the original application.

I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d), of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)			Priority Claimed	
(Number)	(Country)	(Day/Month/Year Filed)	Yes	No
(Number)	(Country)	(Day/Month/Year Filed)	Yes	No
(Number)	(Country)	(Day/Month/Year Filed)	Yes	No

I hereby claim the benefit under title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below

(Application Number)	Filing Date
(Application Number)	Filing Date

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Number)	Filing Date	(Status -- patented, pending, abandoned)
(Application Number)	Filing Date	(Status -- patented, pending, abandoned)

I hereby appoint William E. Alford, Reg. No. 37,764; Farzad E. Amini, Reg. No. P42,261; Aloysius T. C. AuYeung, Reg. No. 35,432; William Thomas Babbitt, Reg. No. 39,591; Carol F. Barry, Reg. No. 41,600; Jordan Michael Becker, Reg. No. 39,602; Bradley J. Bereznak, Reg. No. 33,474; Michael A. Bernadicou, Reg. No. 35,934; Roger W. Blakely, Jr., Reg. No. 25,831; Gregory D. Caldwell, Reg. No. 39,926; Ronald C. Card, Reg. No. P44,587; Thomas M. Coester, Reg. No. 39,637; Donna Jo Coningsby, Reg. No. 41,684; Stephen M. De Klerk, under 37 C.F.R. § 10.9(b); Michael Anthony DeSanctis, Reg. No. 39,957; Daniel M. De Vos, Reg. No. 37,813; Robert Andrew Diehl, Reg. No. 40,992; Matthew C. Fagan, Reg. No. 37,542; Tarek N. Fahmi, Reg. No. 41,402; James Y. Go, Reg. No. 40,621; James A. Henry, Reg. No. 41,064; Willmore F. Holbrow III, Reg. No. P41,845; Sheryl Sue Holloway, Reg. No. 37,850; George W Hoover II, Reg. No. 32,992; Eric S. Hyman, Reg. No. 30,139; Dag H. Johansen, Reg. No. 36,172; William W. Kidd, Reg. No. 31,772; Erica W. Kuo, Reg. No. 42,775; Michael J. Mallie, Reg. No. 36,591; Andre L. Marais, under 37 C.F.R. § 10.9(b); Paul A. Mendonsa, Reg. No. 42,879; Darren J. Milliken, Reg. 42,004; Lisa A. Norris, Reg. No. P44,976; Chun M. Ng, Reg. No. 36,878; Thien T. Nguyen, Reg. No. 43,835; Thinh V. Nguyen, Reg. No. 42,034; Dennis A. Nicholls, Reg. No. 42,036; Kimberley G. Nobles, Reg. No. 38,255; Daniel E. Ovanezian, Reg. No. 41,236; Babak Redjaian, Reg. No. 42,096; William F. Ryann, Reg. 44,313; James H. Salter, Reg. No. 35,668; William W. Schaal, Reg. No. 39,018; James C. Scheller, Reg. No. 31,195; Jeffrey Sam Smith, Reg. No. 39,377; Maria McCormack Sobrino, Reg. No. 31,639; Stanley W. Sokoloff, Reg. No. 25,128; Judith A. Szepesi, Reg. No. 39,393; Vincent P. Tassinari, Reg. No. 42,179; Edwin H. Taylor, Reg. No. 25,129; John F. Travis, Reg. No. 43,203; George G. C. Tseng, Reg. No. 41,355; Joseph A. Twarowski, Reg. No. 42,191; Lester J. Vincent, Reg. No. 31,460; Glenn E. Von Tersch, Reg. No. 41,364; John Patrick Ward, Reg. No. 40,216; Charles T. J. Weigell, Reg. No. 43,398; Kirk D. Williams, Reg. No. 42,229; James M. Wu, Reg. No. P45,241; Steven D. Yates, Reg. No. 42,242; Ben J. Yorks, Reg. No. 33,609; and Norman Zafman, Reg. No. 26,250; my patent attorneys, and Andrew C. Chen, Reg. No. 43,544; Justin M. Dillon, Reg. No. 42,486; Paramita Ghosh, Reg. No. 42,806; and Sang Hui Kim, Reg. No. 40,450; my patent agents, of BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP, with offices located at 12400 Wilshire Boulevard, 7th Floor, Los Angeles, California 90025, telephone (310) 207-3800, and Alan K. Aldous, Reg. No. 31,905; Robert D. Anderson, Reg. No. 33,826; Joseph R. Bond, Reg. No. 36,458; Richard C. Calderwood, Reg. No. 35,468; Jeffrey S. Draeger, Reg. No. 41,000; Cynthia Thomas Faatz, Reg No. 39,973; Sean Fitzgerald, Reg. No. 32,027; John N Greaves, Reg. No. 40,362; Seth Z. Kalson, Reg. No. 40,670; David J. Kaplan, Reg. No. 41,105; Charles A. Mirho, Reg. No. 41,199; Leo V. Novakoski, Reg. No. 37,198; Naomi Obinata, Reg. No. 39,320; Thomas C. Reynolds, Reg. No. 32,488; Kenneth M. Seddon, Reg. No. 43,105; Mark Seeley, Reg. No. 32,299; Steven P. Skabrat, Reg. No. 36,279; Howard A. Skaist, Reg. No. 36,008; Steven C. Stewart, Reg. No. 33,555; Raymond J. Werner, Reg. No. 34,752; Robert G. Winkle, Reg. No. 37,474; and Charles K. Young, Reg. No. 39,435; my patent attorneys, and Thomas Raleigh Lane, Reg. No. 42,781; Calvin E. Wells; Reg. No. P43,256, Peter Lam, Reg. No. P44,855; and Gene I. Su, Reg. No. 45,140; my patent agents, of INTEL CORPORATION; and James R. Thein, Reg. No. 31,710, my patent attorney; with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith.

I verily believe the original patent to be wholly or partially inoperative:

by reason that the patent claims less than I had a right to claim in the patent. The claim or claims will be partly inoperative in failing to protect against infringement of all embodiments of my invention. Thus, I hereby indicate a desire to seek broadened claims as indicated in the Preliminary Amendment filed herewith. I also hereby affirm that this reissue application was filed diligently upon discovery of the errors indicated below. The errors arose in the prosecution of the original application which resulted in the issuance of the patent. The attorney prosecuting the original application failed to

appreciate the scope of the invention, and thus, limited the claims as indicated below. The error arose without any deceptive intention on my part. I further acknowledge my duty to disclose information which is material to the examination of the application under 37 CFR § 1.56.

Specifically, in claim 1, the phrases "camera" (column 9, line 58), "a sensor configured to capture an image and generate a sensor output signal representing the captured image" (column 9, line 59), "coupled to receive the sensor output signal" (column 9, line 61), "configured to apply multiple gain level to the sensor output signal" (column 9, line 62), and "configured to provide a control signal to the amplifier" (column 9, line 65) are individually not necessary to distinguish claim 1 from the prior art or to make claim 1 definite.

Specifically, in claim 11, the phrases "for capturing an image, comprising a camera" (column 10, line 27), "a sensor configured to capture the image and generate a sensor output signal representing the captured image" (column 10, line 29), "coupled to receive the sensor output signal" (column 10, line 32), "controls to apply multiple gain level to the sensor output signal" (column 10, line 33), and "configured to receive the sensor output signal, and wherein the processor is configured to provide a control signal to the amplifier" (column 10, line 35) are individually not necessary to distinguish claim 11 from the prior art or to make claim 11 definite.

Specifically, in claim 17, the phrases "for enhancing the dynamic range of a sensor output signal representing a captured image" (column 10, line 56), "the sensor output signal in response to gain settings contained in a gain map" (column 10, line 59), and "updating the gain settings contained in the gain map in response to changes in the sensor output signal" (column 10, line 63) are individually not necessary to distinguish claim 17 from the prior art or to make claim 11 definite.

Full Name of Sole/First Inventor Eric C. Hannah

Inventor's Signature ______________________ Date ______________

Residence Pebble Beach, California (City, State) Citizenship USA (Country)

Post Office Address ______________________

Full Name of Second/Joint Inventor ______________________

Inventor's Signature ______________________ Date ______________

Residence ______________ (City, State) Citizenship ______________ (Country)

Post Office Address ______________________

Full Name of Third/Joint Inventor ______________________

Inventor's Signature ______________________ Date ______________

Residence ______________ (City, State) Citizenship ______________ (Country)

Title 37, Code of Federal Regulations, Section 1.56
Duty to Disclose Information Material to Patentability

(a) A patent by its very nature is affected with a public interest. The public interest is best served, and the most effective patent examination occurs when, at the time an application is being examined, the Office is aware of and evaluates the teachings of all information material to patentability. Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section. The duty to disclosure information exists with respect to each pending claim until the claim is cancelled or withdrawn from consideration, or the application becomes abandoned. Information material to the patentability of a claim that is cancelled or withdrawn from consideration need not be submitted if the information is not material to the patentability of any claim remaining under consideration in the application. There is no duty to submit information which is not material to the patentability of any existing claim. The duty to disclosure all information known to be material to patentability is deemed to be satisfied if all information known to be material to patentability of any claim issued in a patent was cited by the Office or submitted to the Office in the manner prescribed by §§1.97(b)-(d) and 1.98. However, no patent will be granted on an application in connection with which fraud on the Office was practiced or attempted or the duty of disclosure was violated through bad faith or intentional misconduct. The Office encourages applicants to carefully examine:

(1) Prior art cited in search reports of a foreign patent office in a counterpart application, and

(2) The closest information over which individuals associated with the filing or prosecution of a patent application believe any pending claim patentably defines, to make sure that any material information contained therein is disclosed to the Office.

(b) Under this section, information is material to patentability when it is not cumulative to information already of record or being made or record in the application, and

(1) It establishes, by itself or in combination with other information, a prima facie case of unpatentability of a claim; or

(2) It refutes, or is inconsistent with, a position the applicant takes in:

(i) Opposing an argument of unpatentability relied on by the Office, or

(ii) Asserting an argument of patentability.

A prima facie case of unpatentability is established when the information compels a conclusion that a claim is unpatentable under the preponderance of evidence, burden-of-proof standard, giving each term in the claim its broadest reasonable construction consistent with the specification, and before any consideration is given to evidence which may be submitted in an attempt to establish a contrary conclusion of patentability.

(c) Individuals associated with the filing or prosecution of a patent application within the meaning of this section are:

(1) Each inventor named in the application;

(2) Each attorney or agent who prepares or prosecutes the application; and

(3) Every other person who is substantively involved in the preparation or prosecution of the application and who is associated with the inventor, with the assignee or with anyone to whom there is an obligation to assign the application.

(d) Individuals other than the attorney, agent or inventor may comply with this section by disclosing information to the attorney, agent, or inventor.